

Initial impact of a soil disturbance technique (disc harrowing) on Orthoptera in a grass heath in Breckland, UK

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Abstract

On a Breckland grass heath in eastern England, soil disturbance methods such as disc harrowing employed to benefit endangered plants such as tower mustard, *Arabis glabra*, could also create exposed ground for localized insects, specifically the mottled grasshopper, *Myrmeleotettix maculatus*. Orthoptera of disc-harrowed strips on a grass heath at Santon Warren in Norfolk, UK, were monitored in 2018 and 2019. Data analysis focused on two target species, field grasshopper, *Chorthippus brunneus*, and *M. maculatus*, which are likely to respond positively to the creation of early successional habitat. Of the two species, *M. maculatus* was found in significantly high abundance on the disc-harrowed strips, whereas *C. brunneus* was not. The species richness of Orthoptera did not appear affected by harrowing, although three species at this location (lesser marsh grasshopper, *Chorthippus albomarginatus*, long-winged conehead, *Conocephalus fuscus*, and Roesel's bush-cricket, *Roseliana roeselii*) need taller vegetation than was present on the disc-harrowed strips.

Keywords

Acrididae, bare earth, bush-cricket, conservation, grasshoppers, heathland, Tettigoniidae

Introduction

Breckland is a biodiversity hotspot in the UK; 25,500 species were recorded in a recent audit led by the University of East Anglia (Dolman et al. 2012). Over 2,000 of these species were of national conservation concern. The flora includes over 120 nationally rare and threatened plant species with many dependent on the remaining dry grassland and heathland that survived afforestation in the 20th century (Robertson and Hawkes 2017). The grasshopper fauna (Orthoptera: Acrididae) of Breckland is relatively impoverished in comparison, with only six native species (55% of the national total of 11 species) (Richmond 2001, Gardiner 2018a). Despite the dearth of species, grasshoppers are an important component of grassland ecosystems, consuming up to 8% of net primary production (Köhler et al. 1987). Grasshoppers are a crucial link in food chains as prey for spiders and avian predators in particular (Latchinsky et al. 2011). Densities of grasshoppers often exceed 3 adults/m² in dry acid grassland and heathland, indicating that they can be an abundant food source (Gardiner et al. 2002). Be-

cause of this, grasshoppers have been listed as a key invertebrate group in the Breckland Natural Area profile.

Different grasshopper species have contrasting microclimatic preferences (humidity and temperature) that drive the diversity of assemblages (Gardiner et al. 2002, Gardiner and Dover 2008). Short grassland and heathland swards may be unfavorable for some grasshoppers due to high microclimatic temperatures (>44°C) at 10 cm above the soil surface (Gardiner and Hassall 2009), which can lead to shade-seeking behavior and vigorous escape responses in several grasshopper species. The optimum air temperature for the development of grasshoppers in the UK is thought to be 35–40°C (Willott 1997), although at high elevations in the Alps (>2000 m above sea level), temperatures never reach these levels, limiting the reproductive potential of the common green grasshopper, *Omocestus viridulus* (Berner et al. 2004).

Responses to microclimatic temperatures differ between species. For example, the mottled grasshopper, *Myrmeleotettix maculatus*, is a short sward specialist, and its small size may be an adaptation for the high temperatures it experiences (Willott 1997). Contrastingly, *O. viridulus*, a tall grass species in the UK (Marshall and Haes 1988), is a large insect that can overheat in short, hot grasslands/heathlands and, therefore, avoids those habitats (Gardiner 2010). Tall grassland may also have higher humidity that is more favorable for this grasshopper (Berner et al. 2004).

Warren and Büttner (2009) highlighted that disturbance caused by military activities can help conserve populations of the blue-winged grasshopper, *Oedipoda caerulescens*, which needs plentiful (30–50%) bare earth in its habitat. Many insects can be classified as either disturbance-dependent or disturbance-averse, depending on the level of disturbance of the vegetation cover they need to persist. Bare earth provides sites where grasshoppers can bask to warm up (exposed soil is often much hotter than surrounding vegetation; Key 2000) and where adult females of species such as the field grasshopper, *Chorthippus brunneus*, which lay their egg pods in exposed soil (Choudhuri 1958), can deposit their egg load after mating. Bare earth is the earliest stage of succession and is often lacking in grasslands due to a dearth of soil disturbance caused by an absence of grazing livestock. Grasslands without management can become tall and rank and have little exposed soil (Grayson and Hassall 1985, Ausden and Treweek 1995, Gardiner 2018b).

Myrmeleotettix maculatus was the scarcest species recorded in a recent survey of Breckland (Gardiner 2013, 2018a), being observed at only two sites (East Wretham Heath and Thetford Warren Lodge). In the Breckland survey, there seemed to be an absence of the open ground for this disturbance-dependent grasshopper. At Thetford Warren Lodge, it was abundant on lichen heath, a seemingly scarce habitat at the other survey sites.

It is the aim of this short communication to determine the initial impact of the soil disturbance technique of disc harrowing on Orthoptera of a grass heath in Breckland, UK, focusing on two disturbance-dependent species: *C. brunneus* and *M. maculatus*.

Methods

Site.—The study site on Santon Warren (52°27'43.2468"N, 0°40'23.8224"E) in Breckland, Suffolk, UK, was a grass heath composed of fine-leaved grasses (*Agrostis* and *Festuca* spp.) with rare annual plants (tower mustard, *Arabis glabra*) dependent on soil disturbance for their persistence. The grass and lichen heath developed on a sandy soil (with flint) and underlying chalk bedrock. Formerly, rabbit (*Oryctolagus cuniculus*) grazing checked grass growth and scrub development, but since the myxomatosis outbreak in the 1960s, this influence has declined. Therefore, other methods of creating bare ground were required to encourage the proliferation of rare plants.

Soil disturbance technique.—Two strips of grass heath (300 m length) with little exposed bare ground (<10%) were randomly selected for soil disturbance with agricultural discs attached to the back of a tractor. The primary aim of disc harrowing in this area was to promote the abundance of the plant *A. glabra* (Neal Armour-Chelu personal communication). The vertical discs harrowed the surface and upper layers of the soil (Robertson and Hawkes 2017) to a width of 2.5 m and a depth between 8–18 cm. Disc harrowing has been regularly employed in Breckland in recent years to conserve rare plant populations and promote invertebrate abundance (Robertson and Hawkes 2017). The two strips were disc-harrowed in February 2018 with adjacent grass heath left untouched (Fig. 1). Vegetation was allowed to naturally regenerate on the strips.

Orthoptera sampling methods.—In each disc-harrowed strip and in an adjacent control strip, a 1-m wide x 300-m long transect (the same length for the disc-harrowed strip and the control) was established, closely following the methodology of Gardiner et al. (2005) and Gardiner and Hill (2006). The disc-harrowed and control strips were parallel to each other but at least 10 m apart to reduce the risk of double counting. Two target species, *C. brunneus* and the more localized *M. maculatus*, were the focus of adult monitoring, although individuals of all species were also recorded to determine assemblage composition and species richness. The former grasshopper is an abundant species in Breckland, while *M. maculatus* is localized and probably declining in response to the lack of soil disturbance on grass heath (Gardiner 2018a). The two target species should be model insects for studying the responses to disc harrowing as both require bare earth during their life cycle for basking and oviposition (Marshall and Haes 1988). It is acknowledged that the narrow nature of the disc-harrowed strips meant that frequent movements of grasshoppers between bare earth and surrounding unmanaged heath were unavoidable. Therefore, the surveys were a snapshot of strip usage, indicating their favorability for basking or oviposition, rather than as a self-contained breeding habitat.

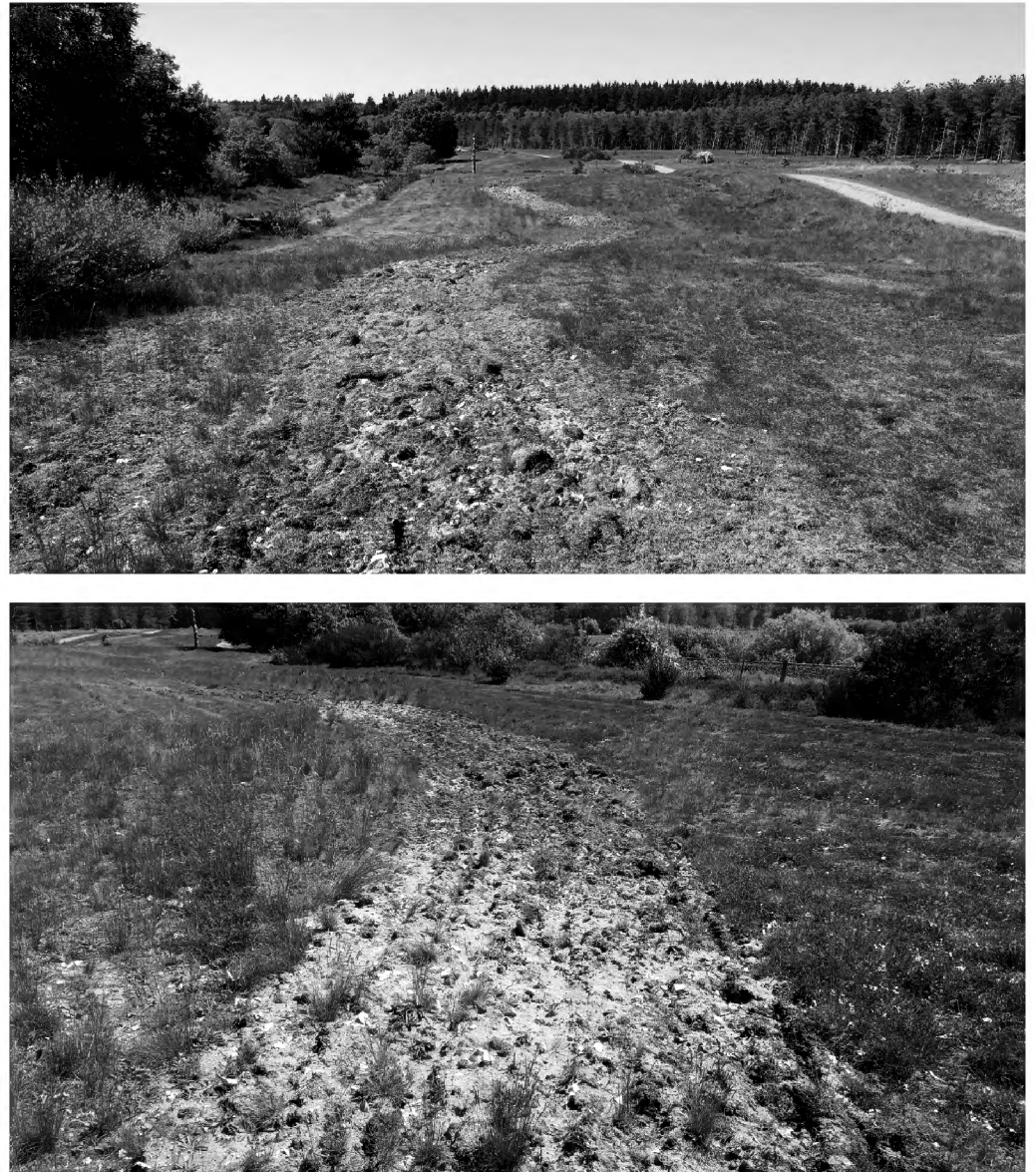


Fig. 1. Disc-harrowed strips in May 2018, three months after disc harrowing, showing partial revegetation and variation in exposed substrate.

Each transect was walked at a slow, strolling pace (2 km/hr) from May–July of 2018 and 2019 (5 surveys in each year, 10 in total). Nymphs flushed from a 1-m wide band in front of the observer were recorded along the center of the 2.5 m harrowed strip and in the control. As it is difficult to distinguish between species in the early instars, nymphs of both species were lumped together for recording purposes. The surveys were undertaken in vegetation sufficiently short (<50 cm) to minimize the possibility of overlooking nymphs in tall grass (Gardiner et al. 2005). With practice, it was relatively easy to ascertain the species of adults without capture (Gardiner and Hill 2006). In addition to nymphs and adults of the two grasshopper species, other orthopteran species were counted on transects to provide an estimate of assemblage abundance and species richness. The weather conditions on survey days were favorable for insect activity, being largely sunny and warm (>17°C).

Statistical analysis.—The counts for each transect were standardized to 0.1 ha to give a clearer indication of usage of strips and control. To correct for non-normality, the data for both grasshopper species and the species richness were square-root transformed (Heath 1995). The mean density/0.1 ha of nymphs, adults of *C. brunneus* and *M. maculatus*, and overall species richness were compared between the disc-harrowed strips and control in both years using a 2-way ANOVA.

Results

A total of 811 nymphs (70% of total recorded) were observed on the disc-harrowed strips in both years combined, compared to 353 on the control transects. Adults of both species were numerous (both years combined, *C. brunneus*: 729 individuals, *M. macu-*

latus: 559). The disturbance-dependent species *M. maculatus* was almost exclusively recorded on the disc-harrowed transects (552 adults observed, 99% of total) compared to the control (just 7 adults). Adults of *C. brunneus* were more evenly distributed (434, or 60%, on disc-harrowed transects and 295 on control).

Densities of nymphs (Fig. 2) were not significantly different between disc-harrowed strips and controls ($F = 6.77$, $P = 0.06$) or year ($F = 2.18$, $P = 0.21$) with no interaction between factors ($F = 0.01$, $P = 0.93$). Densities of *C. brunneus* adults were not significantly different between disc-harrowed strips and controls ($F = 0.98$, $P = 0.38$) or year ($F = 1.14$, $P = 0.35$) with no interaction between treatment and year ($F = 0.21$, $P = 0.67$). In contrast to *C. brunneus*, densities of *M. maculatus* adults were significantly different between disc-harrowed strips and controls ($F = 299.58$, $P = 0.0001$) but not between years ($F = 3.35$, $P = 0.14$) and with no interaction between factors ($F = 0$, $P = 1$).

Overall, five species of Orthoptera were recorded on the sparsely vegetated disc-harrowed strips and eight on the controls (Table 1). All species apart from *C. brunneus* and *M. maculatus* were in low abundance (≤ 20 adults). Common green grasshop-

Table 1. Species of Orthoptera recorded on disc-harrowed strips and unmanaged controls.

Species	Disc-harrowed	Control	Total
<i>Chorthippus brunneus</i>	434	295	729
<i>Myrmeleotettix maculatus</i>	552	7	559
<i>Stenobothrus lineatus</i>	15	16	31
<i>Omocestus viridulus</i>	4	16	20
<i>Roeseliana roeselii</i>	0	11	11
<i>Pseudochorthippus parallelus</i>	2	5	7
<i>Chorthippus albomarginatus</i>	0	3	3
<i>Conocephalus fuscus</i>	0	2	2
Total	1007	355	1362

per, *Omocestus viridulus*, lesser marsh grasshopper, *Chorthippus albomarginatus*, meadow grasshopper, *Pseudochorthippus parallelus*, and stripe-winged grasshopper, *Stenobothrus lineatus*, were all more numerous on the controls than the disc-harrowed strips (Table 1). No bush-crickets were recorded on the harrowed strips, with long-winged conehead, *Conocephalus fuscus*, and Roesel's bush-cricket, *Roeseliana roeselii*, being confined to the taller vegetation (>30 cm) of the control heath. Despite the differing species lists, disc harrowing had no impact on species richness ($F = 3.46$, $P = 0.14$) nor did it differ with years ($F = 0.54$, $P = 0.50$), with no interaction between treatment or year ($F = 0.76$, $P = 0.43$).

Discussion

In many grasslands, grazing can create patches of bare earth (through trampling of the soil by hooves) that provides an environment for grasshopper oviposition and basking (Bazelet and Gardiner 2018, Gardiner 2018b). In the absence of grazing animals, such as sheep and cattle, artificial methods of soil disturbance can be used to establish exposed soil (Robertson and Hawkes 2017, Hawkes et al. 2019a,b). In this study, disc harrowing was utilized to encourage the germination of rare plant species such as *A. glabra* in Breckland. In turn, it appears that disc harrowing also benefited the localized grasshopper *M. maculatus*, which is a species found in early successional ground with bare earth and lichen cover (Marshall and Haes 1988).

In this study, *M. maculatus* was almost exclusively found on the soil disturbed strips when compared to unmanaged dry heath, a similar situation to other Breckland soil disturbance studies. In research plots at nearby Stanford Training Area (STANTA), 60 *M. maculatus* were recorded in pitfall traps on cultivated grass heath, whereas none were captured in undisturbed controls (Robert Hawkes personal communication). The grasshopper is at an advantage on exposed soil, particularly where there is a high stone content, due to its mottled coloration that provides excellent camouflage (Gardiner 2014).

In the pioneering Breckland study by Dolman and Sutherland (1994), shallow rotavation produced bare soil interspersed with fragments of vegetation including the remains of grass tussocks, moss, and lichen. It appears that disc harrowing produces a similar diverse habitat. The microhabitats of the harrowed strips varied from unvegetated mobile sand, stony ground, to soil sparsely covered with lichens and mosses. *Myrmeleotettix maculatus* was recorded in all of these situations (Fig. 3), and it is likely that the continued presence of this localized grasshopper may be dependent on the provision of an appropriate matrix of exposed soil and early successional vegetation in Breckland.

The most abundant grasshopper, *C. brunneus*, had no preference for the disc-harrowed strips. In a study of its response to sward height in Essex, *C. brunneus* preferred grasslands with swards

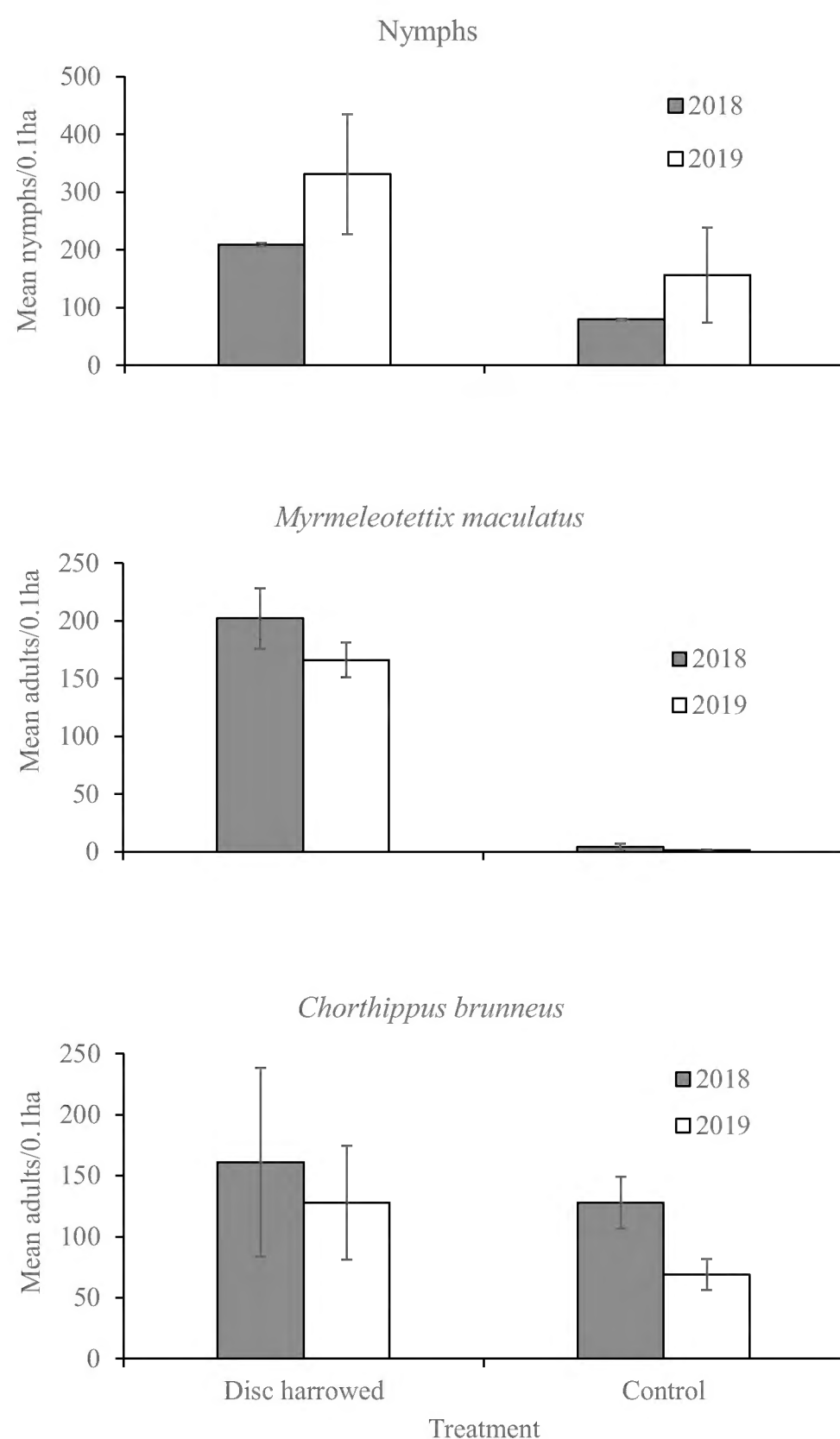


Fig. 2. Nymph (both species combined) and adult density for two grasshopper species.



Fig. 3. Typical *Myrmeleotettix maculatus* habitat: stony, exposed soil with little vegetation. Photo credit: T. Gardiner.

10–20 cm in height (Gardiner et al. 2002), suggesting that the harrowed strips lacked the required patches of tall grass for shelter and feeding (Bernays and Chapman 1970a,b), despite an abundance of oviposition habitat. Consequently, without taller refuges from the often excessive microclimatic temperatures of bare soil, larger species (*C. brunneus* at 15–25 mm as compared to *M. maculatus* at 12–19 mm; Marshall and Haes 1988) may disperse to unmanaged vegetation to seek shade (Gardiner and Hassall 2009).

The 2.5 m-wide strips were probably too narrow to fulfil all the needs of either grasshopper species, probably with frequent movements between the exposed soil and adjacent grass heath. Adults of *M. maculatus* were abundant on the strips: perhaps they utilized the exposed ground for basking and oviposition.

In reality, soil disturbance is undertaken to conserve rarer species than the orthopterans recorded in this study. The primary driver at Santon Warren is the conservation of the endangered plant *A. glabra*. The favorable habitat for *M. maculatus* demonstrates a knock-on benefit for a non-target insect. It is possible that disc harrowing may also benefit other invertebrates that require soil disturbance, such as the declining small heath butterfly, *Coenonympha pamphilus*, that was regularly sighted on the strips. Green tiger beetles, *Cicindela campestris*, were also seen on the disc-harrowed strips along with many species of Hymenoptera.

Hawkes et al. (2019a) report that ground-disturbance increased the numbers of woodlark, *Lullula arborea*, while multi-taxa invertebrate responses were mixed in response to various ground treatments (Hawkes et al. 2019b), with only 'priority' carabid beetles influenced by cultivation treatment. Hawkes et al. (2019b) further outlined that landscapes with soil disturbance treatments had a higher species richness of ants, beetles, and true bugs than those without.

This small-scale study presents evidence that soil disturbance on a grass heath using a disc harrow may produce enhanced habitat for localized disturbance-dependent species such as *M. maculatus*. Although orthopteran species richness was unaffected by disc harrowing, the strips may be too hot or bare of vegetation for species not recorded on the strips, such as the bush-crickets *C. fuscus* and *R. roeselii* (Table 1). Therefore, soil disturbance should be embedded within the management of a grass heath mosaic that includes long grassland benefitting the full range of Orthoptera present (Table 1).

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